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Mid-Holocene (ca. 6000 – 3500 ^{14}C yr B.P.) climates in the Atacama Altiplano of the south Central Andes: humid or dry? - Limnogeological, geomorphological, hydrological and vegetational evidence for widespread mid-Holocene aridity.

Martin Grosjean and co-workers*

Swiss Federal Institute for Snow and Avalanche Research SLF, 7260 Davos Switzerland, grosjean@slf.ch

* B. Ammann, M. Camacho, M.A. Geyh, R. Kern, J. Kulemeyer, C. Kull, A. Kunz, C. Lucas, L. Lupo, B. Messerli, L. Núñez, D. Oezen, U. Schotterer, H. Schreier, W. Tanner, B. Valero, J. van Leeuwen, H. Veit

The view of general mid-Holocene aridity in the Atacama Desert and Altiplano [e.g., 1-4] has recently been challenged [5]. The paleoclimate archives in question are fine-grained organic (peat, diatomite) and inorganic silt/sand size alluvial deposits which formed in relatively steep valleys east and north-east of the Salar de Atacama between ca. 7000 and 3000 ^{14}C yr B.P. Consensus exists about i) the timing of the deposition, ii) the depositional environment (shallow lake, wetland, calm water flow) and iii) the existence of higher groundwater tables in these valleys during that time. Disagreement exists about the interpretation of the high groundwater table. Whereas the Tucson group [5] interprets the high groundwater table as a result of a generally more humid climate (compared with today, but less humid than the late-glacial/Early Holocene climate), the Swiss group [1,2] concludes generally more arid conditions during that time. The key site it the Quebrada Puripica, but other sites show comparable features suggesting that Q. Puripica is representative at the regional level.

Our current knowledge in Q. Puripica is that the depositional environment during the humid early Holocene (prior to ca 7500 ^{14}C yr B.P.) was erosive. Sediments from that period of time are so far missing in the valley. However, in Quebradas further south (e.g., near Tambillo in the Salar de Atacama [5], Q. Las Zorras and Barda near Salar Punta Negra [6]), late-glacial/early Holocene wetland sediments were found near the mouth of the valleys, on alluvial fans and in delta areas, where the hydraulic regime was probably already influenced by the paleolake high-stands in the big Salars [6].

At around 6000 ^{14}C yr B.P., the depositional environment in Q. Puripica changed from the erosion to the accumulation mode. Subsequently, accumulation of fine-grained sediments lasted until ca. 3000 ^{14}C yr B.P., when the regime flipped back to linear erosion and the entire sediment pack of several tenths of meters was cut down to bedrock within about 1000 years, and modern conditions (steady small river flow mainly in a bedrock channel) were established [1].

The key-question is: How was the climate and how were hydrological conditions which allowed for a high groundwater table and accumulation of fine-grained sediments in Q. Puripica? Our line of argument is as follows: Accumulation of fine materials in a valley

requires decreasing river flow and calm conditions. Accumulation of fine-grained but permeable material (in Q. Puripica mainly sand, silt and peat, some gravel layers) in the valley bottom forms an aquifer with a markedly decreased velocity of the subsurface water flow. In this environment, the groundwater table may rise despite a greater cross-section in the valley and overall decreased surface and subsurface discharge as expected in generally more arid conditions. Thus we conclude a generally more arid climate than today with overall decreased water discharge. We infer that river discharge must have been smaller than today, because the modern Rio Puripica dissected the sediments down to bedrock in an environment of linear erosion as observed today. This is very different from the Tucson interpretation which concludes that periods of increased groundwater tables directly reflect higher water discharge and thus more humid climates.

Sedimentary processes in river systems are very complex, and little is known about the behavior of such systems. This is the reason why we do not make a strong case with the sediments in Q. Puripica. However, we find a highly consistent picture comparing our Puripica interpretation with regional limno-geological data from endorheic Lake Miscanti [2] and regional geoarchaeological data [7, 8 most recent review]. Furthermore, a broad range of paleoenvironmental data in adjacent areas to the NE and SW (which are the potential moisture sources for precipitation in the Atacama Desert) show a consistent picture of widespread mid-Holocene aridity: Millennia-scale low lake levels in Lago Titicaca [e.g. 4] and minimal ice accumulation rates in the Sajama ice core [3] are well established and integrate meso- to large-scale climate conditions in the tropical rainfall area of the Bolivian Central Andes. Also the areas with extratropical winter rainfall adjacent to the SW of the Atacama show widespread mid-Holocene aridity [9, 10].

However, we emphasize that the mid-Holocene period in the Atacama Desert was not a boring uniform dry climate phase with a complete silence of geomorphic processes. Instead, many of the currently known paleoclimate archives provide information about violent, short-lived (daily to multi-decade) and high amplitude moisture changes which resulted in significant geomorphic processes and shaping of the landscape.

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